2008-04-01

Defense Acquisition Management for Systems-of-s

Daniel DeLaurentis

Defense Acquisition Management for System-of-systems

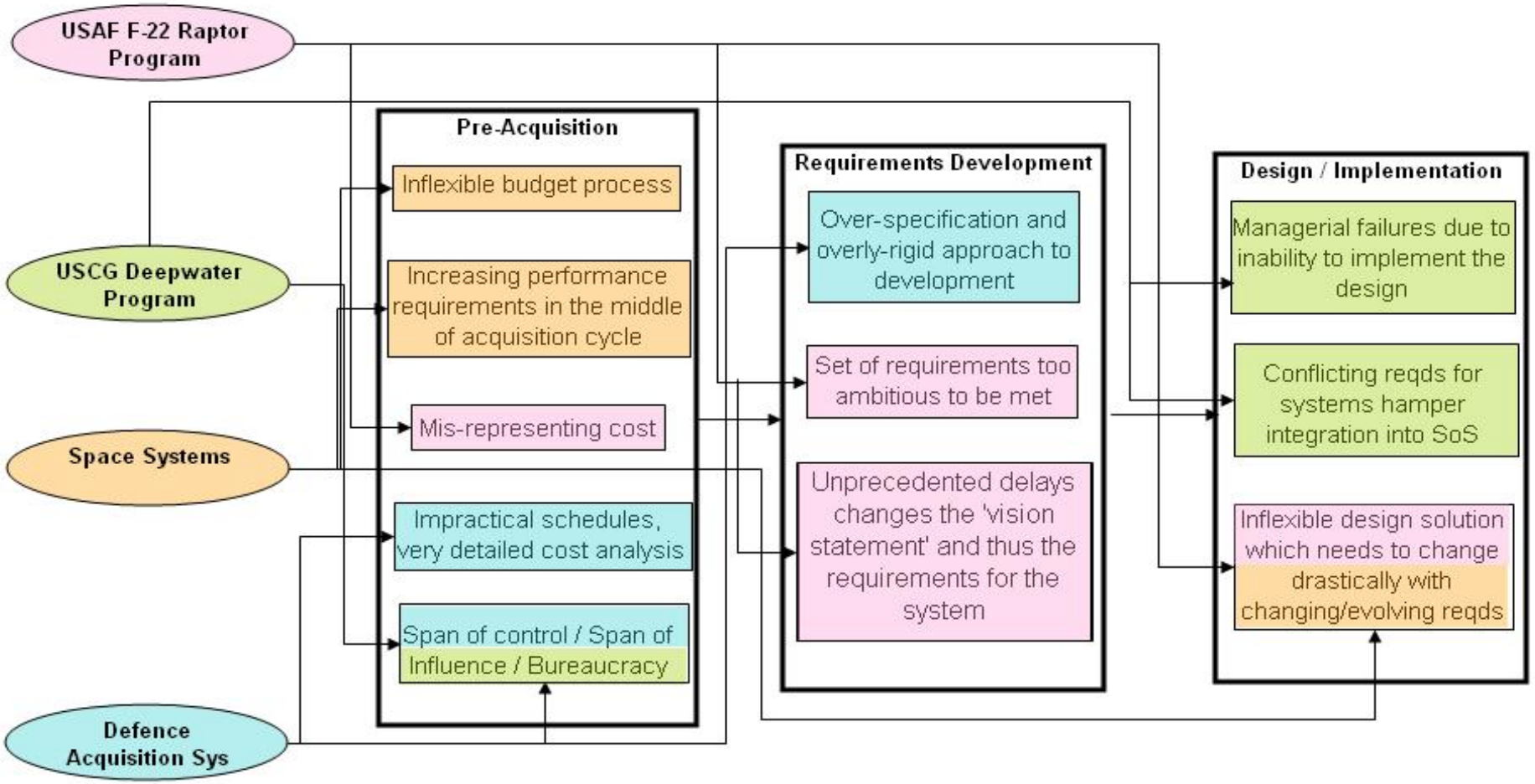
Dr. Daniel DeLaurentis
Email: ddelaure@purdue.edu
Shayani Ghose
Email: ghose@purdue.edu

Purdue University
School of Aeronautics & Astronautics
West Lafayette, IN.

Sponsor: NPS Acquisition Research Program

Motivation

Data indicates a variety of challenges for SoS Acquisition are at hand.



Root causes* of failure within acquisition processes

- a) *misalignment* of objectives among the systems,
- b) limited *span of control* of the SoS engineer on the component systems of the SoS,
- c) *evolution* of the SoS,
- d) *inflexibility* of the component system designs,
- e) *emergent behavior* revealing hidden dependencies within systems,
- f) *perceived complexity* of systems and
- g) the challenges in *system representation*

* Partially based on: Rouse, W. (2007, June). Complex Engineered, Organizational and Natural Systems. *Systems Engineering*, 10, 3., pp. 260-271

Our Research Questions

1. What are the underlying systems engineering (SE) and program management functions that are affected by complexities due to *evolution* of SoS acquisition and *span-of-control*?

   We hypothesize that a large *span-of-control* for the SoS engineers and managers makes the acquisition process time-efficient for directed requirement dependencies, primarily by encouraging distinct groups implementing dependent requirements to collaborate.

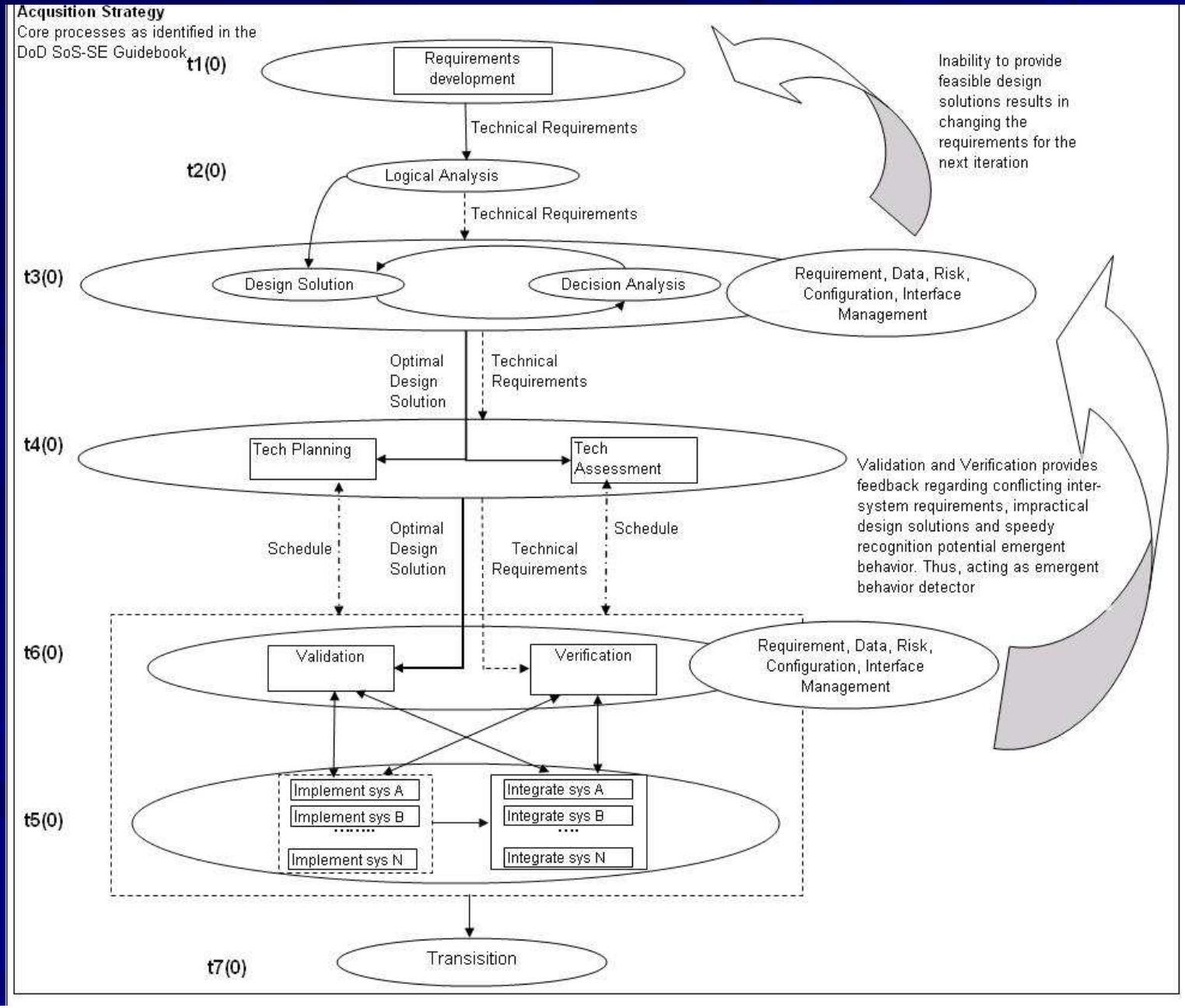
2. How can Exploratory Modeling **generate insights** and approaches to improve the probability of program success?

Development of an Exploratory Model for SoS Acquisition

1. *Pre-Acquisition Model* : Understand the influence of external stakeholders on the acquisition process

2. *Acquisition Strategy Model* :
   - Based on the 16 technical management and technical systems engineering processes outlined in the Defense Acquisition Guidebook (5000 series) applied to an SoS environment (SoS-SE Guide)
   - Conceptual model depicts the processes in a hierarchical setting to show the flow of control between the processes throughout the acquisition life-cycle.

Acquisition Strategy – The Paper Model



Overall Description – Computational Model

System Inputs:

- Total time for entire SoS to be designed and implemented
- Number of requirements
- Total budget for SoS

Logic:

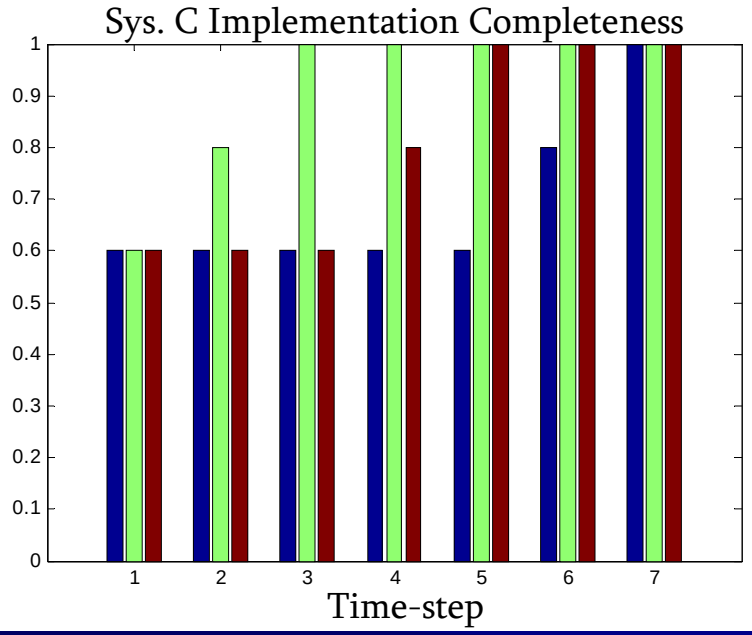
- Uses Agent Based Modeling (ABM) implemented in MATLAB
- Uses probabilistic model for disrupter actuation and system solution

Outputs:

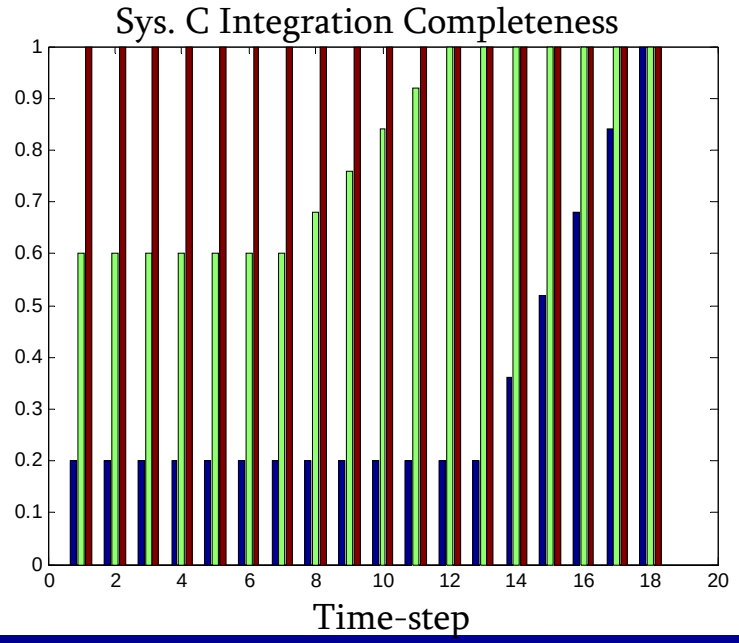
- Total time needed for SoS development
- Information at every time step:
  - Stage (status) of requirement
  - Fraction of completion of each requirement at each stage
  - System integration/implementation statistics

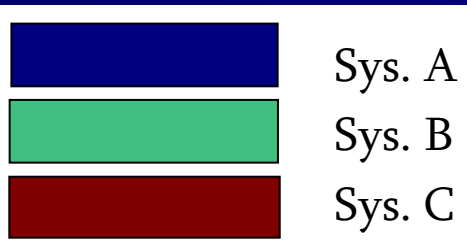
Implementation and Integration of Dependent Systems (no disruptions)

Implementation of Sys. C proceeds with respect to Sys.'s A, B, and C



Integration of Sys. C is dependent on the other systems as well!



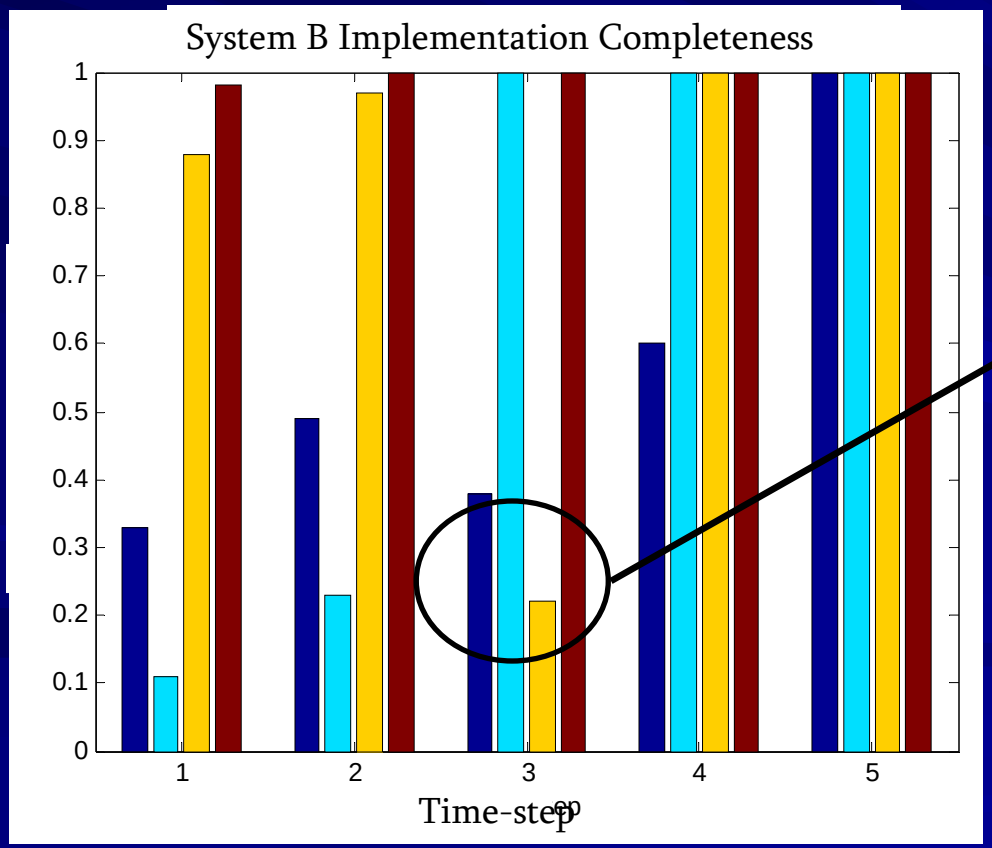


Waiting for B

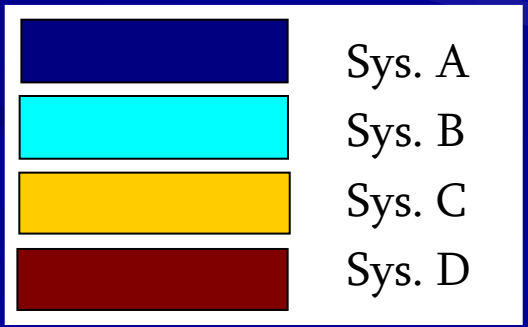
Waiting for A

Effects of Disruptors

- Inevitable disruptions on both system-level and requirement levels will occur
- *Technology Assessment* is able to immediately trace and resolve the problem. This prevents the development from stalling or regressing over multiple time-steps.

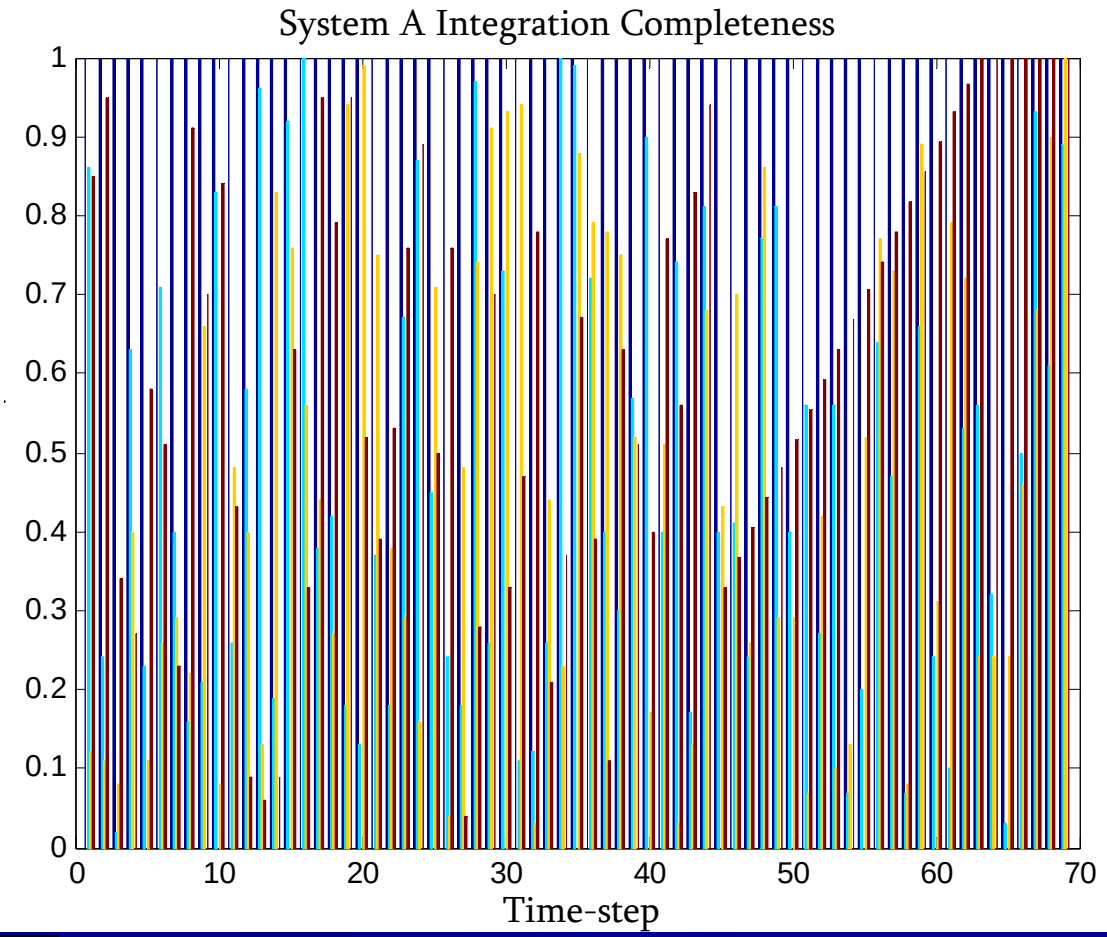


Negative Disruptions correspond to system re-engineering and lower completeness level in Implementation and Integration phase



Vulnerability to Disruptions

- Some systems have a much higher risk factor. This means that they are more vulnerable to negative disruptions in their development.
- **Analysis:** Higher risk of disruptions means the system/systems take more time to complete the stage. There is also the possibility that this may never happen.
- Conditional Probability



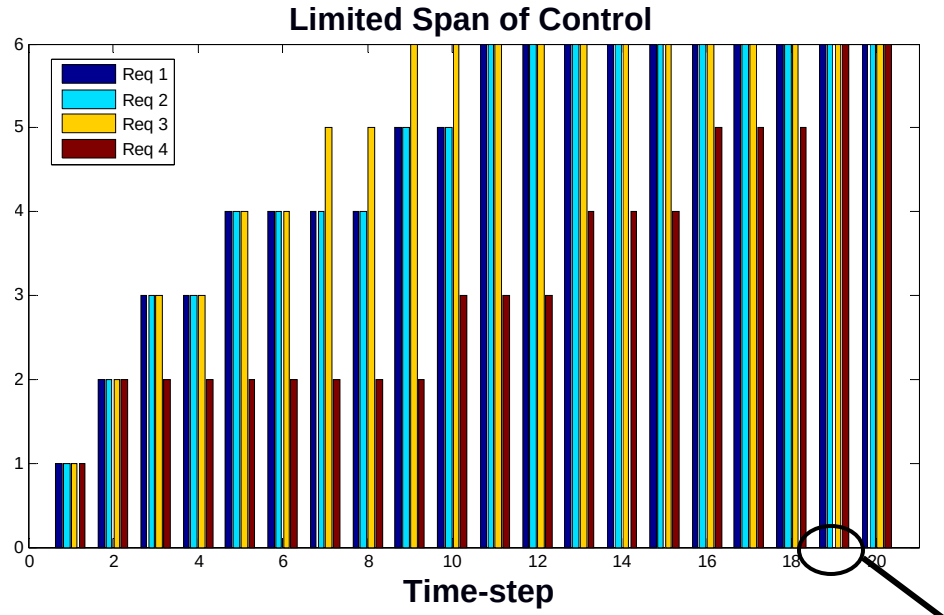
$$p(A) = p(A|B)p(B) + p(A|B')p(B')$$

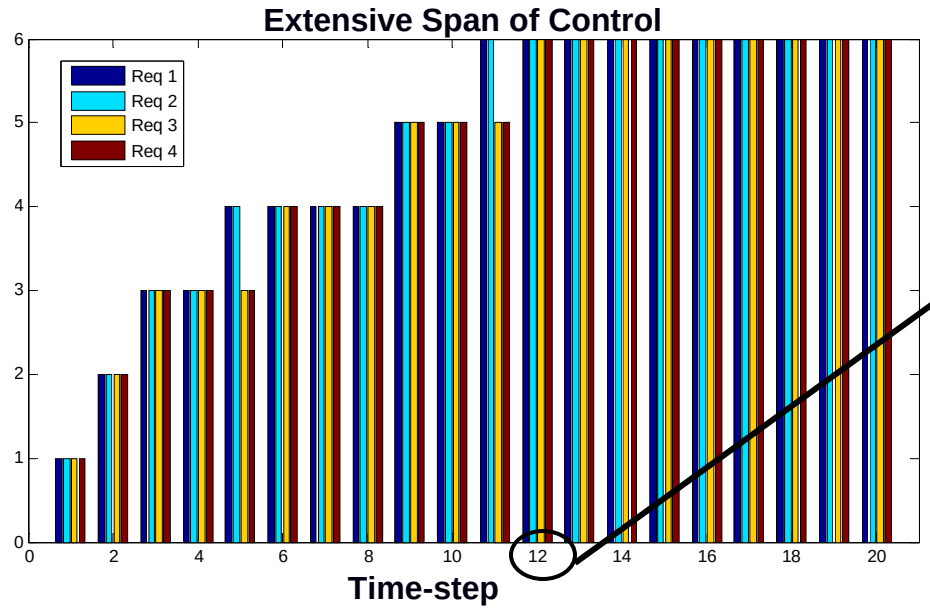
A= Event a system is hit
B= Event a queue is hit

p(B)=50% chance of the Integration queue being hit by disruptions.
p(A|B)=99% chance for a system in the queue being affected.

p(A)= 49.5% chance of a system being hit by disruptions

Effect of Span-of-control





Stages of Requirement Completion:

1. Requirement Development
2. Logical Analysis
3. Design Solution
4. Decision Analysis
5. Implementation
6. Integration

In the case of limited *Span-of-Control*, acquisition process completes in 19 time-steps. Whereas, in extensive *Span-of-Control* process completes in 12 time-steps.

Uniqueness of Model

- Dynamic and scalable Model allows Requirements and Systems to be added/changed at any point in the acquisition process.
- Heterogeneity: Component systems differ in their level of completeness for *Integration* and *Implementation* phases. They represent legacy systems and new systems in various stages of development.
- Probabilistic approach for disruptors affecting systems is based on real acquisition models where higher risk means greater chance for delays during development (*Design, Integration and Implementation*).
- Parallel processing for Requirements and Systems fulfilling a given Requirement depends on *'span-of-control'* of SoS engineers and managers.

Overall focus is on "Learning" and "exposition of complexities", not on actual use for program management.

Future Work

- Using Future Combat Systems (FCS) as a case-study for the exploratory model
- Adding fuzzy probabilistic boundaries defining *span-of-control*
- Generating, testing and analyzing different scenarios dealing with introduction of requirements and systems at different times and with different levels of completeness.
- Creating user-interfaces for the model

References

- Defense Acquisition Guidebook. Retrieved April 4, 2008, from Defense Acquisition Guidebook Web site: https://akss.dau.mil/dag/TOC_GuideBook.asp?sNode=R2-3-2&Exp=Y
- (2006). SoS Systems Engineering. Retrieved March 2, 2008, from Systems and Software Engineering Web site: http://www.acq.osd.mil/sse/ssa/initi atsos-se.html
- Saunders, T.et al. (2005, July). Report on System-of-Systems Engineering for Air Force Capability Development. *USAF Scientific Advisory Board.* SAB-TR-05-04.
- Rouse, W. (2007, June). Complex Engineered, Organizational and Natural Systems. Systems Engineering, 10, 3., pp. 260-271
- Sage, A. and Biemer, S. (2007) Processes for System Family Architecting, Design, and Integration. IEEE Systems Journal. 1,1. pp. 5-16.
- Maier, M. (1998).Architecting Principles for System-of-Systems. Systems Engineering. 1, 267-284.
- Anderson, M, Burton, D, Palmquist, M.S., & Watson, J.M (1999, May). The Deepwater Project - A Sea of Change for the U.S. Coast Guard. *Naval Engineers Journal*, RetrievedApril 01,2008,from http://www.prosoft.tv/aseaofchange.pdf.
- *United States Coast Guard Acquisition Directorate*. (1998). Coast Guard Recapitalization Fact Sheet. Retrieved January 3, 2008, from http://www.uscg.mil/acquisition/programs/pdf/CG-9recap.pdf
- Allen, T. (2007, April). Statement on the Converted 123-foot Patrol Boats and Changes to the Deepwater Acquisition Program.*USCG Press Release*.Retrieved June 1, 2007 from www.piersystem.com/go/doc/786/154307
- Caldwell, S. L. (2006, June).Coast Guard: Observations on Agency Performance, Operations and Future Challenges. *Government Accountability Office (GAO)* Retrieved January 3, 2008, from http://www.gao.gov/new.items/d06448t.pdf
- Fowler, C. A. (1994, August). The Defense Acquisition System Too Late for the Scalpel; Bring Out the Meataxe! *IEEE Aerospace and Electronic Systems Magazine*, *9*, 8., pp. 3-6.
- Spring, B. (2005,October). Congressional Restraint Is Key to Successful Defense Acquisition Reform. *The Heritage Foundation.* Retrieved March 26, 2008, from http://www.heritage.org/Research/NationalSecurity/bg1885.cfm
- Riccioni, E. (2005,March). Description of Our Failing Defense Acquisition System as Exemplified by the History,
- Nature and Analysis of the USAF F-22 Raptor Program. *Project On Government Oversight.* Retrieved March 4, 2008 from http://www.pogo.org/m/dp/dp-fa22-Riccioni-03082005.pdf
- 14 Capaccio.,T.(2006, December). Boeing Systems Delayed, 11 Others Killed in Proposed Army Budget.*Bloomberg*. Retrieved June 1, 2007 from http://www.bloomberg.com/apps/news?pid=newsarchive&sid=amNoYrTtynxQ

Questions?

Backup Slides